Claims

1. A projection optical system for enlarged projection from a primary image surface existing at a reducing side to a secondary image surface existing at an enlarging side, comprising:

a first optical system that forms an intermediate image of the primary image surface; and

a second optical system having a concave reflector that forms the secondary image surface according to the intermediate image,

wherein a light beam travels from the center of the primary image surface to the center of the secondary image surface, crosses an optical axis of the first optical system, reflects on the concave reflector, crosses the optical axis again, and reaches the secondary image surface.

2. The projection optical system according to claim 1,

wherein the first optical system and the second optical system include surfaces that are rotationally symmetric about a common optical axis.

3. The projection optical system according to claim 2,

wherein the second optical system comprises only the concave reflector.

4. The projection optical system according to claim 2,

wherein the second optical system has a convex reflector

toward an enlarging side or reducing side of the concave reflector.

5. The projection optical system according to claim 2, wherein the first optical system forms the intermediate image toward the primary image surface rather than the concave reflector of the second optical system.

6. The projection optical system according to claim 5, wherein conditional equation (1) below is satisfied where Ls is a length of the first optical system and Si is a distance between the first optical system and the intermediate image.

(1) $Si/Ls < 2$

7. The projection optical system according to claim 5, wherein conditional equation (2) below is satisfied where S12 is a distance between the first optical system and the concave reflector and R is a paraxial curvature radius of the concave reflector.

(2) $S12 > |R|/2$

8. The projection optical system according to claim 4, wherein conditional equation (3) below is satisfied where SR12 is a distance between the convex reflector and the concave reflector.

(3) $SR12 > |R|/2$

9. The projection optical system according to claim 2,

wherein the concave reflector is a rotationally symmetric and aspheric surface about the optical axis.

10. The projection optical system according to claim 9,

wherein a function indicating a shape of the rotationally symmetric and aspheric surface contains an aspheric coefficient of odd-numbered degree.

11. The projection optical system according to claim 9,

wherein the concave reflector is shaped to decrease a curvature against a paraxial curved surface as the concave reflector becomes distant from the optical axis.

12. The projection optical system according to claim 4,

wherein the convex reflector contains at least one rotationally symmetric and aspheric surface.

13. The projection optical system according any of to claims 2 through 5,

wherein the first optical system contains one or more rotationally symmetric and aspheric surfaces.

14. A projection-type image display apparatus comprising:

a light source;

modulation means for modulating and outputting light

radiated from the light source based on a video signal; and

a projection optical system for enlarged projection from a primary image surface toward the modulation means to a secondary image surface toward a screen,

wherein the projection optical system includes:

a first optical system that forms an intermediate image of the primary image surface; and

a second optical system having a concave reflector that forms the secondary image surface according to the intermediate image,

wherein a light beam travels from the center of the primary image surface to the center of the secondary image surface, crosses an optical axis of the first optical system, reflects on the concave reflector, crosses the optical axis again, and reaches the secondary image surface.

15. The projection-type image display apparatus according to claim 14,

wherein the first optical system and the second optical system include surfaces that are rotationally symmetric about a common optical axis.

16. The projection-type image display apparatus according to claim 14,

wherein the screen is transmissive;

wherein the screen is disposed at the front of a cabinet that contains the light source, the modulation means, and the

projection optical system; and

wherein the projection optical system provides enlarged projection onto the transmissive screen from its rear.

17. The projection-type image display apparatus according to claim 16,

wherein the projection optical system is provided at the bottom of the cabinet; and

wherein there is provided a plane mirror that is disposed at the top of the cabinet, reflects light output from the projection optical system, and deflect the light so as to reach the transmissive screen.

18. The projection-type image display apparatus according to claim 17,

wherein the second optical system forms a pupil for the intermediate image onto the secondary image surface outside a light flux traveling from the plane mirror to the transmissive screen surface.

19. The projection-type image display apparatus according to claim 14,

wherein a light beam travels from the center of the primary image surface to the center of the secondary image surface and crosses the optical axis within a vertical plane; and

wherein there is provided reflection means that reflects the light beam between the first and second optical systems and

deflects the light beam within a horizontal plane.

20. The projection-type image display apparatus according to any of claims 14 through 19, comprising:

at least one plane reflector for freely directing a light path reflected on the concave reflector,

wherein conditional equation (4) below is satisfied where θ is an angle formed between the screen and an outmost light beam that is directed toward the screen from a plane reflector positioned immediately before the screen and passes a position farthest from the screen.

(4) $0.6 > \tan\theta > 0.05$